CHAPTER TWO

CONCEPT EXPLORATION PHASE
(Pre-Milestone I)

INTRODUCTION

Based on our discussion in Chapter One, we have seen that the Sponsor plays the leading role in the initial establishment of the tentative A_o thresholds which are consistent with the mission needs analysis on which the system requirement is based. At Milestone 0, with the approval of the OR, the Sponsor formally established a preliminary A_o threshold (or range) which became the basis on which the Concept Exploration phase proceeds. In the acquisition period following Milestone 0 and prior to Milestone I, the initial system concepts adopted in the OR will be further developed and refined. Alternative approaches will be explored which will meet the established A_o preliminary threshold range. For major acquisition projects, this concept exploration effort will be directed and coordinated by a Program Manager assigned at Milestone 0. For smaller acquisition projects, the concept development effort will be the responsibility of an existing office in the Developing Agency. In either case, the role of the Sponsor during this period changes. Mission requirements and a range of preliminary A_o threshold values consistent with these requirements have been put in place. Now the Sponsor must ensure that concept exploration proceeds in a manner which will result in the identification of specifically defined systems concept which meets the OR requirements at the lowest overall cost. Perhaps the major issues to be reconciled in this phase are the cost trade-offs inherent in alternative approaches to obtaining the projected A_o of the system. Thus, the Sponsor must concentrate on monitoring and evaluating A_o as it relates to the projected overall cost of the system.

The relevant concept of costs to be employed by the Sponsor must be system life-cycle costs. System life-cycle costs include:

1. Research and development costs
2. Acquisition costs
3. Introduction costs
4. Logistic support costs
5. Disposition costs.

Thus, to be effective in the Concept Exploration phase the Sponsor must not only be able to effectively evaluate the general composition of the A_o index for a given system alternative but must also be fully conversant with the cost trade-offs which exist for a given system alternative. The objectives of the Sponsor's review are two-fold. First, the projected A_o associated with any given system alternative under consideration must be realistic when decomposed into the reliability, maintainability, and supportability elements on which it is based. This implies that the Sponsor must be assured that the data and assumptions which support the projected A_o for a given alternative are auditable and defensible. Second, given that the A_o values projected for each alternative approach to the system are individually realistic, the Sponsor must ensure that the systems concept selected for development and validation represents the most cost-effective choice based on the trade-offs which exist between life-cycle costs, A_o and mission effectiveness.

REFINING A_O REQUIREMENTS

Preliminary A_O threshold values consistent with the operational or mission effectiveness of the system have been specified in the JMSNS/OR at the overall or major system level at Milestone 0. During this phase, the system-level A_O threshold value will be refined and extended by the Program Manager through analysis at the subsystem (and potentially the component) level. <u>The Sponsor plays an important role in this effort to more fully define A_O requirements and should accomplish the following key action steps.</u>

1. <u>Review and Approve the Use Plan</u>

   First, the initial system mission requirement which evolved earlier through warfare analysis or simulation must be more specifically developed in explicit operational terms. This effort, called the Use Study or Use Plan in acquisition categories I and II, will be conducted by the Program Manager. As outlined in MIL-STD-1388-1A, the Use Study will define the actual application planned for the system and will establish the detailed deployment or operational environment envisioned for the system. Deployment cycles, utilization rates, etc. as outlined in the Use Study should be validated by the Sponsor against the initial Mission Needs Determination which drove the preliminary A_O threshold established at Milestone 0. Any changes in the intended use of the system should be reflected in revised mission effectiveness or system effectiveness requirements and, where appropriate, in the A_O thresholds used to guide the Concept Exploration Process. The Sponsor should formally approve the Use Plan at Milestone I.

2. <u>Review and Validate the A_O Allocation</u>

   Second, the Sponsor must ensure that the major system-level A_O threshold requirement is properly and consistently translated and allocated to the subsystem or, where feasible, to the component level within the overall system. This process of allocation, accomplished by the Program Manager, should be reviewed by the Sponsor to determine:

   a. Are subsystem/equipment A_O threshold values realistic given technology, Fleet operating experience, and preliminary logistic support plans?

   b. Are subsystem/equipment A_O thresholds for these subsystems common to other major systems consistent with A_O requirements for these systems?

   c. Are the reliability and maintainability parameters for any existing government-furnished subsystems/equipments to be used in the new system consistent with the assumptions specified for the new system?

   d. Do subsystem/equipment reliability, maintainability, and supportability parameters allow adequate flexibility for potential "growth" in system/equipment A_O requirements as the development process proceeds?

   This second major effort essentially recognizes that most new systems involve a hierarchy of subsystems and components and that this system/equipment relationship must be accurately and consistently represented in the refinement of A_O threshold values. Essentially, the documentation of A_O requirements at the system, subsystem, and components levels must be clearly and explicitly linked and an audit trail (top to bottom) established to allow the Sponsor to effectively evaluate the reasonableness and consistency of proposed subsystem/component changes. Each time a subsystem/component-level A_o requirement changes, the impact of the change on other related subsystem/components and on major system A_o must be reviewed to confirm system effectiveness requirements are maintained. No subsystem/component change may be made in isolation without recognizing the hierarchial relationships which exist in the major system. The Sponsor should require that the Developing Agency document these A_o relationships at the system/subsystem/ component level and that assumptions made at one level are consistent with those made at other levels in the system hierarchy.

MONITORING AND EVALUATING A_o

Key Action Steps

The process of monitoring and evaluating A_o by the Sponsor begins in earnest following Milestone 0 as the system concept exploration begins and as specific system proposals and configurations are evaluated in terms of development cost, schedule, technical performance, reliability, maintainability, and logistic support costs associated with these system alternatives. Of particular concern to the Sponsor at this stage in the acquisition process should be issues of system supportability. Based on DODI 5000.1 of 19 November 1985 (NOTAL), the Navy policy since 1980 has been that readiness and supportability questions are equally as important as cost, schedule, and performance issues and that the emphasis on system supportability must begin at the start of the acquisition process. It is recognized that this general policy thrust is not yet well-established in practice. Nevertheless, based not only on the supportability costs of today's Navy systems but also on the direct impact which system supportability will ultimately have on system effectiveness, the focus on supportability parameters--including all elements of logistic support--is crucial to the successful development and deployment of the system. The Sponsor must begin in this early phase to understand and to assess the assumptions and factors which are utilized to develop preliminary system alternatives in response to the issuance of the Operational Requirement (OR) document. Thus, in review the systems concept explored in this phase, the Sponsor must ensure that the supporting analysis is consistent with the A_o preliminary threshold range established and that the underlying components of A_o are reasonable relative to the current level of technology, Fleet procedures and practices, and the general level of logistic support which may be expected in the actual operation of the system. Three specific Sponsor actions are required in this phase:

1. <u>Review and Confirm the Baseline Comparison System</u>

   First, the Sponsor must confirm that the Baseline Comparison System (BCS) selected by the Program Manager for comparison and for development of projected system parameters is realistic and appropriate. Function, technical performance, and reliability estimates for the BCS should be reviewed and used for comparison with general system parameters for the proposed system.

2. <u>Validate the Use Plan</u>

   Second, the Sponsor should validate that the Plan for Use developed by the Program Manager is complete, clearly defined, and consistent with the mission needs analysis initially formulated prior to Milestone 0. The Sponsor should be sensitive to any changes in system utilization and deployment planning which may be a part of the Use Study but not a part of the mission needs analysis which determined preliminary A_O threshold values. Where system technical performance requirements or intended usage have changed, the Developing Agency should be required to demonstrate that these changes are spelled out in the Use Plan and that any related changes required in the preliminary A_O threshold value have been properly incorporated into the analysis and planning and are reflected in the A_O threshold established at Milestone I. It is recommended that the Sponsor formally sign the Use Plan indicating approval and acceptance as a valid statement of the intended application of the system.

3. Review and Validate the Integrated Logistics Support Plan (ILSP)

Third, the Sponsor must review and validate the initial ILSP which will subsequently evolve from the LSA process in later stages. Estimates and analysis will, in this phase, typically be quite general. Most estimates will be at the major system level and will likely be extrapolations from the BCS chosen. Moreover, a number of system options may still be active candidates for consideration.

Because the specific system definition may be unclear at this point, a general paper prototype model of the system alternative selected is perhaps the most realistic expectation for the Sponsor. This general paper specification may be expected to change over time and to become more detailed; however, it is important for the Sponsor to force development of the general paper prototype of the system prior to Milestone I and to further require the definition of the general system parameters of reliability, maintainability, and logistic support envisioned for the system. It is recognized that these parameter definitions will be gross approximations in most cases. However, major inconsistencies with current technical capability, Fleet experience, and logistic support can be identified even in this early stage. For example, system proposals which call for system reliability well beyond any currently deployed systems of a similar type or proposals which are based on an MLDT which is far shorter than current Navy levels must be challenged by the Sponsor at this point. The Developing Agency must be able to effectively document and support the source/validity of these estimates. Failure to do so will potentially jeopardize the viability of the system once fully developed and deployed.

Basic Data Requirements

Supporting data to allow the Sponsor to evaluate the A_O preliminary threshold (or range) proposed by the Program Manager at Milestone I may be defined on two levels. First, there are the major supporting input documents to the establishment of the preliminary A_O threshold developed by the Program Manager. These supporting documents, which should be reviewed in detail by the Sponsor, include:

- Proposed system specification (and functional descriptions of any particular design alternatives under consideration)
- Results of MIL-STD-1388-1A, Use Study and Comparative Analysis.

The major supporting data sources become not only inputs to the Sponsor review of the preliminary A_O threshold, but are also inputs to the operational scenario analysis or use plan for the system discussed earlier. The Sponsor will rely on these macro-level data sources as general statements of how the system will be acquired, how it will be employed, and how it will be supported over its life-cycle. While admittedly much of this general planning and support data will be tentative at this stage of acquisition, it is an invaluable source of information to allow the Sponsor to understand and evaluate the preliminary A_o threshold for the system.

At a lower, more specific level of detail are the discrete parameters estimates or projections made by the Developing Agency which, in combination, determine the A_o threshold envisioned for the system. Here the Sponsor should review the rationale used for determining what are "comparable systems" within the context of MIL-STD-1388-1A LSA and the reasonableness of the sources of data on those comparable systems. We will discuss these data sources and uses in detail in later chapters; however, in this early stage, basic micro-level data requirements may be categorized generally as follows:

1. Failure Rates: Failure rates are the purview of the Navy's engineering community and will typically be addressed by the technically-oriented mathematicians and engineers resident in supporting Systems Command organizations. Based on very early discussion of mission scenario and system operating characteristics, a technical determination or judgment must be made as to the expected failure rate for the system envisioned. This initial treatment must include:

    a. Wartime operating environments, mission scenarios, and required operating characteristics. If the expected wartime operating environment or mission profile is expected to change failure rates, a separate wartime failure rate must be developed. Since existing Navy data bases or similar systems will be essentially peacetime failure rates, extrapolation to wartime rates must, in most cases, be judgmental. Nevertheless, such a determination must be made.

    b. An explicit consideration of subsystem failure rates for those critical subsystems which would render the system equipment inoperable. Expected failure rates for those subsystems essential to the operation of the overall system must be estimated. Additionally, the operating relationships of these critical subsystems must be developed (via a block wiring diagram approach, for example) so that redundancies and specific operating relationships are recognized in the determination of the overall system failure rate.

    For purposes of evaluating failure rates prior to Milestone 0, the best sources of data for similar systems are:

    - The Aviation 3-M Maintenance Data Collection System (aviation systems)
    - The NAVSEA Reliability, Maintainability, and Availability (RMA) Design Data Base (shipboard systems).

Each of these data sources contains failure rate data at the equipment level which is appropriate for estimating MTBF early in the acquisition.

2. Repair Times: The second key element in the A_o index is an estimate of system repair time at the organizational level of maintenance. The estimate, specified as MTTR, assumes that all required parts, personnel, training, publications, and test equipment are available and measures the "inherent maintainability" of the proposed system in its intended operating environment. Repair time estimates should be based on the best data and judgment from the Navy's maintenance community and

should be based on the maintenance plan envisioned for the system. Prior to Milestone I, before the formulation of a maintenance plan specific to the system under consideration, estimates of MTTR will generally be derived from the general operating concept of the system coupled with selective use of repair data for similar (BCS) systems.

Repair times are a part of both the NAVSEA RMA data base and the Aviation MDS system. These repair time data are equipment-specific and apply to the organizational level of maintenance. MTTR ranges are typically low relative to the other elements of the A_o index. As a result, the accuracy of MTTR estimates in the overall A_o index is not critical. For example, given an MTBF of 1,000 hours and an MLDT of 125 hours, ranges of MTTR between zero and 10 hours bound the projected A_o between 0.88 and 0.89. An OPNAV review of a wide range of existing Navy systems in 1981 revealed that a 3-hour MTTR was representative for over 90 percent of the equipments surveyed. This baseline estimate, tempered by conceptual or design plans and by empirical data for similar system, will be adequate to represent MTTR in A_o threshold determination prior to Milestone I. Following Milestone I, as the explicit system concept is finalized and actual system demonstration and validation begins, the MTTR estimate must be validated (and adjusted as required) based on test data and engineering analyses of sample results which are specific to the system being acquired.

3. Logistics Delay Times: No single element of the A_o index is as difficult to address as is Mean Logistics Delay Time (MLDT). At the same time, MLDT has a substantive impact on the A_o of any system. Moreover, a significant portion of life-cycle costs are attributable to the MLDT one finally achieves. MLDT must be addressed explicitly from the outset of the acquisition process. Most systems are supported using standard Navy logistics procedures--standard sparing policies, standard maintenance processes and structures, and standard transportation systems. OPNAVINST 4400.12B (NOTAL) provides logistic support delay time goals which are standard to the Navy logistics system. The support structure assumes a three-echelon (consumer, intermediate, and wholesale) inventory structure and a related three-echelon (organizational, intermediate, depot) maintenance structure. Sparing and distribution procedures are geared to provide specified response times to user requirements. Thus, prior to Milestone I the Sponsor should utilize concrete BCS data, adjusted for planned support differences, to evaluate MLDT projections. Any programmatic thresholds recommended by a Program Manager which imply an MLDT below Navy standards must be challenged by the Sponsor. Such nonstandard MLDT projections must be validated to ensure:

a. Support plans and related resources have been defined and adequately programmed to support the nonstandard MLDT.

b. If sparing-to-availability is planned by the Program Manager, OP-04 approval has been received.

c. A rigorous trade-off analysis has been conducted by the Program Manager to assess the impact and cost of improved reliability, maintainability and supportability on projected A_o and that the documented results of this trade-off analysis clearly point to MLDT as the pivotal variable to be reduced.

Accomplishing Key Action Steps

As discussed earlier in the Concept Exploration phase of systems acquisition, the initial A_O threshold range projected at Milestone 0 and included in the JMSNS/OR will be further refined as system concepts/options are more fully defined. The action steps required should be accomplished as follows:

1. Review and Confirm the Baseline Comparison System

   a. Is the BCS selected representative and appropriate and is it fully defined relative to the system proposals being reviewed?

   b. Are all system parameters (reliability, maintainability, and supportability) realistic and achievable based on the BCS, actual Fleet operating experience, technology (as reflected in Navy or private sector technical data bases), and engineering judgment?

2. Validate the Use Plan

   The Use Plan/Use Study (or equivalent) describes the operational use planned for the system. Together with the data relating to the Baseline Comparison System (BCS), the Use Plan allows the Sponsor to monitor and evaluate Program Manager/Developing Agency A_O proposals. The following basic review technique is recommended:

   a. Is the Use Plan consistent with the Mission Needs Analysis which drove earlier development and acquisition decisions?

   b. If changes have been made in the use planned for the system, have these changes been appropriately reflected in the system/mission effectiveness requirements and, in turn, to the elements of system-effectiveness capability, availability, and dependability.

3. Review and Validate the ILSP

   To understand the process of A_O evaluation at this point in the acquisition cycle, the Sponsor must develop a familiarity with the Logistics Support Analysis (LSA) which underlies the Program Manager proposal. As discussed in MIL-STD-1388-IA, LSA is a mandatory step in systems acquisition which:

   a. Assesses the supportability requirements by support element for the system including personnel, training, support/test equipment, maintenance and repair capabilities, spare parts requirements and positioning, and transportation needs.

   b. Evaluates alternative mixes or combinations of policies and procedures for the set of logistics elements outlined above to identify the most cost effective mix given the preliminary A_O threshold range established and the evolving values for reliability (MTBF) and maintainability (MTTR).

   c. Develops logistic support cost projections for the system over its life-cycle for the logistic support alternative or structure considered to be most cost effective.

d. Provides detailed backup plans and analysis for depot maintenance support (the Depot Support Plan) and for supply support (the Supply Support Management plan).

e. Provides the foundation for the derivation of the Integrated Logistics Support Plan (ILSP) which must be available at Milestone I and for the later refinement of this to generate the final ILSP for the system.

The LSA effort is a continuing process throughout the acquisition cycle. Much of the supporting detail noted above will not be available in earlier phases but will be developed as the LSA process proceeds. We will discuss the LSA process in greater detail in Chapter Four.

Prior to Milestone I, the LSA will typically be conducted at the major system level and issues of system supportability will clearly be addressed on a very preliminary basis pending concept demonstration and validation. Nevertheless, the Sponsor must resolve several critical issues in this phase:

a. Does the ILSP reflect comprehensive planning for logistic support and is the maintenance and supply support structure envisioned for the system realistic based on the planned system employment plan and current logistic support performance? Can the Developing Agency provide a document flow analysis which will demonstrate how material availability and time delays generated by the proposed ILSP relate to the MLDT used to develop the proposed A_o threshold?

b. Are all assumptions, data, and computational analyses correct and valid and are these factors used consistently not only within the document, but also in relationship to earlier planning factors and projections?

These specific Sponsor actions in the monitoring and evaluation of A_o over time as systems acquisition proceeds will be discussed in more detail in later chapters. The primary responsibility of the Sponsor prior to Milestone I is to ensure that the systems concept selected is the most cost effective alternative consistent with the preliminary A_o threshold range established.

<u>Documentation Required</u>

Documentation requirements for the A_o threshold at Milestone I have been identified in an earlier section of this Chapter. In addition to the major decision documents required (such as the DCP/NDCP and the TEMP), important supporting documents include:

- The Use Plan
- The ILSP
- Related technical appendices to the DCP/NDCP.

A_O COST TRADE-OFF ANALYSIS

Key Action Steps

This section deals with evaluating the preliminary A_O threshold on the basis of mission objectives and cost trade-offs. Prior to Milestone I, this analysis is perhaps the major responsibility of the Sponsor. Ideally, we would like each system to have an A_O of 1. This is impossible since this would require a system reliability of 1 or, if the system were not 100 percent reliable, it would require instantaneous repair when the system did fail. Moreover, the life-cycle cost of a system is closely connected with the A_O achieved by a system, and the higher the A_O required of a system the higher the life-cycle cost. Consequently, it is important to examine the preliminary A_O threshold range set for a system in terms of both the effectiveness of the system meeting mission objectives and the corresponding life-cycle cost of the system. The Sponsor needs to understand what mission effectiveness of a new system will be at different A_O levels and the corresponding cost of supporting each acceptable A_O level to make efficient decisions on how to allocate the Navy's scarce resources.

1. Confirm Mission Effectiveness to A_O Requirements

The first and primary objective in establishing the preliminary A_O threshold must be mission effectiveness. In Chapter One, we discussed the general methodology that should be used in setting preliminary A_O thresholds in terms of the warfare requirements for the system. Here, the Sponsor must confirm the A_O threshold established. Conceptually, this A_O to mission capability decision should be made prior to any cost trade-offs analysis. The Sponsor should begin by analyzing the relationship which the Program Manager has developed and documented (for each system option) between the platform-level measure of mission effectiveness appropriate in the specific instance (for example, ships mission capability) and the major system-level A_O required to generate this level of platform level effectiveness. Recall that each system option being considered in the Concept Exploration phase has potentially different capability (Co) and dependability (Do) parameters which, together with system A_O will determine mission or system effectiveness. The required level or range of mission effectiveness designated for the system (based on earlier warfare analysis) will, in turn, allow the Sponsor to validate the potential preliminary A_O threshold range proposed by the Program Manager. In Figure 2-1, the mission effectiveness measure chosen as appropriate to the system is Ships Mission Capability (SMC). A minimum SMC of 0.75 has been specified. This required level of mission effectiveness drives a range of A_O values, for systems options considered viable by the Developing Agency, of 0.80 to 0.95 as shown. The presumption must be that any A_O required to meet established mission objectives will, in turn, be achieved at least-cost based on reliability, maintainability, and supportability options. Measuring mission effectiveness as the probability of the system completing its mission or missions within approved scenario(s), the Sponsor should expect to see a graph or similar data) as portrayed in Figure 2-1 illustrating mission effectiveness and A_O relationships for each option or alternative identified during concept development prior to a Milestone I decision to proceed with demonstration and validation of a single option.

The values on the vertical axis (i.e., measures of mission effectiveness) will vary depending on available information. If we must relate system, subsystem, or equipment A_O to platform readiness then effectiveness should be platform

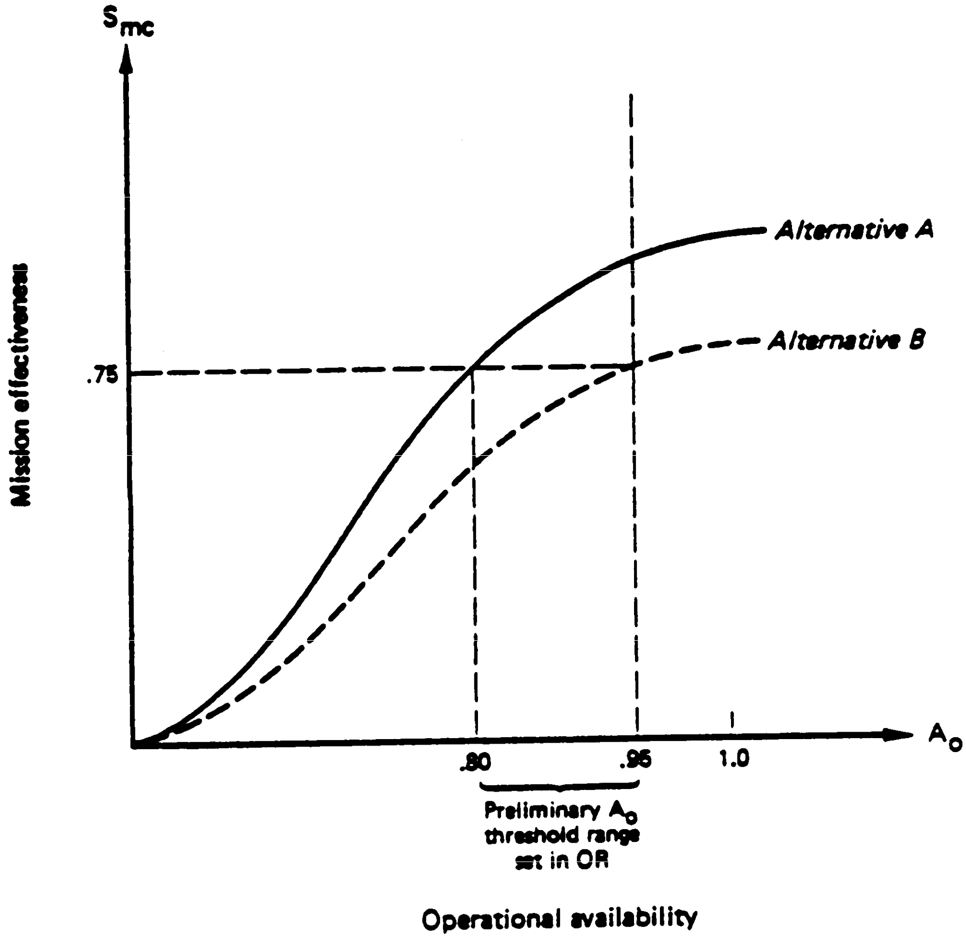

FIG. 2-1: MISSION EFFECTIVENESS

readiness. The effectiveness measure must be carefully chosen to indicate the successful operation of the system in a time-phased wartime scenario approved for the system. In any event, performance characteristics of the system must also be considered and the effectiveness measure must be tied into the probability of the system meeting its mission objectives. As described earlier, it will be the combination of capability, availability and dependability which will determine system effectiveness and platform-level mission effectiveness.

2. Validate A_o to Life-Cycle Cost Relationships

Figure 2-2 portrays cost-to-capability (i.e., cost-to-A_o) curves for system alternatives or options identified during concept exploration. These cost-to-capability curves should be a part of the Program Manager's concept exploration effort and must be documented by the Program Manager with a list of the assumptions about the scenarios and system performance characteristics (i.e., the proposed operating environment and required operational capabilities of the system) that are used in estimating the relationship between A_o and mission effectiveness. As outlined in OPNAVINST 5000.42C, once a preliminary A_o threshold is established, the relationship between and corresponding life-cycle costs of a system must be estimated. This Program Manager estimation effort must be reviewed and validated by the Sponsor as a second step in analyzing the cost to A_o trade-offs. The Sponsor will require cost-to-capability relationships in order to evaluate life-cycle costs to achieve A_o and mission effectiveness for each system alternative.

Costs must be broken down by the Program Manager into various support categories and the cost analysis performed by the Program Manager should seek an A_o value which represents the most cost effective way of achieving the A_o value. This requires evaluating trade-offs among reliability, maintainability, and the various areas of logistic support at the major system level in meeting an A_o threshold range.

Basic Data Requirements

Basic cost elements, definitions, and estimating guidance is contained in a series of DOD instructions (DODI 5000.33 and DODD 4245.6). While many specific costs and other data are a part of the analysis as acquisition proceeds, prior to Milestone I, the data necessary for the Sponsor to effectively evaluate A_o to cost trade-offs provided by the Program Manager may be specified as follows:

1. Technical and logistic support data for the system under consideration. This data includes failure rates, repair times, and logistic delay times. Alternative feasible mixes of these variables which yield the A_o required of the system based on mission effectiveness should be evaluated by the Program Manager, and the Sponsor should confirm that these alternatives have been assessed.

2. For each alternative mix of failure rates, repair times, and logistic delay times being evaluated, both system acquisition and full life-cycle support costs are required.

In the pre-Milestone I phase of systems acquisition, it is unrealistic for the Sponsor to expect that these technical, logistic support, and cost data will be well defined for the specific system under consideration. In most cases, the specific least-cost mix of reliability, maintainability, and supportability which meets the preliminary A_o threshold will not be fully determined by Milestone

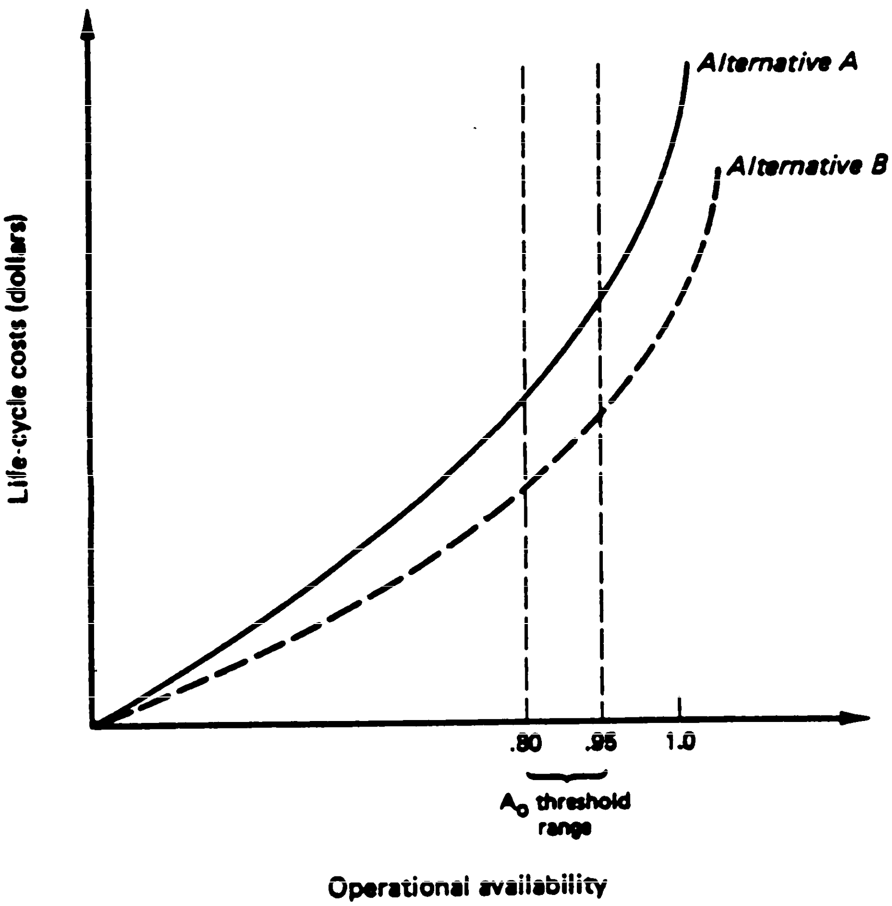

FIG. 2-2: COSTS-TO-A_o CURVES

I. As a result, the cost analysis which supports a Milestone I decision should be based on the best data available for similar baseline comparison systems already in the Navy inventory or on the technical and engineering judgment of the Developing Agency. We have previously discussed these data sources in general terms and delay a more detailed examination of this data until the following chapter.

Accomplishing Key Action Steps 1 and 2

The methodology that is described below is designed to be used by the Program Manager to establish A_o to mission effectiveness and life-cycle cost relationships. The Sponsor should validate and review the Program Manager's cost analysis by sequentially tracking the steps taken. For each step, data sources, assumptions, and results of the analysis should be analyzed by the Sponsor. The basic techniques that are used by the Sponsor to evaluate the relationship between A_o and life-cycle cost, and to review cost trade-offs among factors supporting A_o levels should remain essentially constant over the entire acquisition process. What will change as the acquisition process proceeds is the quality of the data used to execute these techniques. Indeed, system definition, unit costs, reliability and maintainability factors, level of repair and general support concepts, manning and training requirements, to name a few important factors related to system life-cycle costs and A_o, can be estimated and evaluated in the earliest phases of acquisition. These estimates can help the Sponsor make the necessary decisions regarding A_o requirements in terms of the resources needed to maintain an A_o level. Prior to Milestone I, this data may only support very gross trade-offs or gross estimates of A_o. As the acquisition process proceeds the data will become better defined and our estimates of A_o and corresponding system effectiveness and lifecycle costs will also become more accurate.

The Sponsor must evaluate the variable preliminary A_o threshold range set at Milestone 0 on the basis of cost. A_o to cost relationships generally follow the basic pattern shown in Figure 2-3.

However, in developing the relationship of A_o to cost, we must also be sure that resources are allocated by the Program Manager in a cost-effective way among the principle elements of A_o (reliability, maintainability, and logistic support). This is complicated by the fact that logistic support may be packaged in a variety of ways that will provide equivalent logistic delay times at different costs. Consequently, we not only need to consider the possible trade-offs among reliability, maintainability, and logistic support but the possible trade-offs among the elements of logistic support that would provide given levels of A_o for the possible combinations of reliability and maintainability we are considering for the system. This requires that the analysis, conducted by the Program Manager and reviewed/validated by the Sponsor, proceed in two-stages for each system option:

- First, each separate component (MTBF, MTTR, MLDT) of the A_o index must be evaluated in terms of life-cycle costs to obtain any specific level of reliability, maintainability, and supportability. This will typically mean holding the other two components of the A_o index constant for analytical purposes.

- Second, for a given system, alternative combinations of MTBF/MTTR/MLDT must be evaluated and related life-cycle costs aggregated to yield a curve (or a data relationship), such as portrayed in Figure 2-3 for that system option.

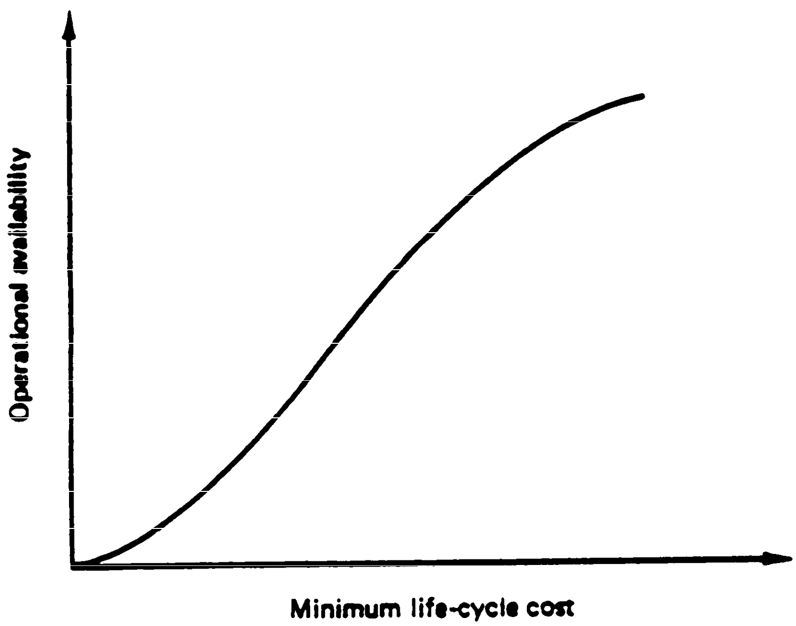

FIG. 2-3: COST-TO-A_o RELATIONSHIP

It is not the intent of this handbook to develop detailed, specific cost estimating methodologies for determining the cost of buying a more (or less) reliable or maintainable system, determining the costs of the elements of integrated logistic support or determining the operating and support costs of a system. The specific methodologies are likely to be system dependent. We will, however, provide a general methodology or approach that will provide the cost to A_o relationships depicted in Figure 2-3. The methodology also provides visibility to ensure that necessary trade-offs among the elements of A_o analysis are made.

The general methodology or approach to be described is important from several points of view. First, it can be used in the earliest phases of acquisition; indeed, as the acquisition process proceeds into the demonstration and validation phase, reliability and maintainability factors become relatively fixed and increasingly difficult and costly to change. It is important, therefore, to consider these trade-offs early. Second, it provides for the establishment of preliminary A_o thresholds on the basis of mission effectiveness; reliability is an important ingredient to measuring mission effectiveness and any changes in reliability requirements on the basis of cost must be evaluated in terms of the mission profile for the system. Third, the methodology is based on using a consistent set of cost and effectiveness techniques throughout the acquisition process. However, as we move through the phases of acquisition, the relevant data becomes more reliable. Consequently, cost and effectiveness estimates become more reliable and discrepancies from previous estimates more easily analyzed. Finally, and most importantly, it provides us with the necessary information to establish the best possible A_o requirement for the system in terms of both cost and system effectiveness. The sequence of analytical steps discussed below should be conducted by the Program Manager, not the Sponsor. In reviewing and evaluating the Program Manager's cost analysis, however, the Sponsor should assess the completeness and reasonableness of the Program Manager's approach by <u>sequentially revisiting each step in the analysis</u>. At each step, the sponsor should:

- Confirm the assumptions made
- Validate the accuracy and appropriateness of the basic data utilized
- Establish the correctness of the computations and results
- Verify the consistency of the approach from step to step
- Ensure that the analysis is adequately described in supporting documents.

After the Operating Requirements (OR) document is completed, possible alternative systems which can meet the system requirements outlined in the OR will be explored. Ideally, each of the systems should be described in complete detail in terms of its master component parts. This is essential for any reasonable cost to A_o analysis.

As we have indicated, this requires that a Baseline Comparison System be developed, that a "paper" prototype of each system (subsystem or equipment) option under consideration be built from the BCS, and that relevant reliability, maintainability and cost data be estimated. At this stage of systems acquisition, much of this data will be defined only at the equipment and major repairable components levels. This realistic data constraint must be recognized by the Sponsor. Nevertheless, as a target, the Sponsor should continually seek a complete indentured description of the system (subsystem/component) which must be developed by the Program Manager:

- The Weapon Replaceable Assemblies (WRAs) must be defined. These are the parts of the system that are removed and replaced at the organizational level to repair the system when it fails.

- The Shop Replaceable Assemblies (SRAs) of each WRA must be defined. These are subparts of the WRAs that are used to repair the WRAs usually at the intermediate or depot-level maintenance facility.

- Piece Parts of each SRA must be defined. These are subparts of SRAs that are used to repair SRAs usually at the intermediate- or depot-level maintenance facility.

The end result of this description should be a list of the following type:

INDENTURE STRUCTURE OF SYSTEM X

```
System X
    WRA (1)
        SRA(l)
            PP(1,1)
            PP(1,2)
        SRA(2)
            PP(2,1)
            PP(2,2)
            PP(2,3)
        SRA(3)
        SRA(4)
    WRA(2)
      .
      .
      .
```

In addition to the indentured structure of the system, the Program Manager must eventually approximate the following for each component (WRA, SRA, and Piece Part):

- Failure Rate

- Repair Rates at each level of repair (intermediate and depot)

- Repair Times at each level of repair

- Quantity per next higher assembly

  - Number of each WRA to system

  - Number of each SRA in its WRA

  - Number of each piece part in its SRA

- Mean Time to Repair (MTTR) each WRA

  - This time is to reflect the time to remove and replace a defective WRA at the organizational level assuming the supply room has a replacement on hand or to repair the WRA at the organizational level if no replacement part is needed.

It is emphasized that the full set of technical and logistic support data outlined above must ultimately be developed in order to fully analyze cost trade-offs in reaching a concrete system specification (at all levels of indenture) and a related A_o threshold on which testing and, eventually, system deployment will be based. This complete set of data will be component, subcomponent, and piece part unique. Specific logistic plans (maintenance, sparing, personnel, transportation, etc.) must be evaluated using related logistic support costs which are derived through the LSA process and detailed maintenance and supply support planning will be conducted to build the ILSP. From the Sponsor's perspective at this stage in the acquisition process, however, the full, specific, component/piece part level data set will not be available. The level of generality in the data will be high and analysis will likely be at the major system level. Subsystem/component level data will, at best, represent broad estimates. The generality of the technical data and the absence of more specific technical data clearly limits the value of the results of our A_o to cost trade-off analysis. While it does not change the approach that the Program Manager should use, the Sponsor must be cognizant of the level of detail at which the analysis can be conducted at this stage in acquisition. Second, even given the lack of specific subsystem/component/piece part data, the accuracy of the data available may be limited at this point in the acquisition process. As system development proceeds, these data accuracy problems will be resolved. Nevertheless, prior to Milestone I, we should recognize that the above data will contain some inaccuracies. Therefore, the description of the system and the corresponding data elements should be based on similar existing systems currently in the Fleet. The necessary data elements should be extracted from Fleet data via the data sources outlined earlier. Reliability elements (failure rates) must be estimated for the "paper" prototype system and should be adjusted to reflect the proposed reliabilities of the system. MTTR should also be estimated and adjusted to reflect the maintainability factors we wish to consider. Finally, unit costs should be adjusted to reflect the cost of the system under the reliability and maintainability factors we set for the system.

Below, we describe the considerations that must be explored in making trade-off analyses or in constructing cost to A_o relationships. We will give a generalized step by step procedure that should be used by the Developing Agency in this type of analysis. It forms the basis of Sponsor review and evaluation of the cost trade-off analysis. At the end of the section, Figure 2-7 provides a flow chart of the methodology.

Step 1

Select one of the systems under consideration. Operating tempo and density of the system on the host platform and the "total buy" should be established before proceeding. If more than one system is under consideration, the following analysis should be carried out for each system and results compared if A_o and the cost of achieving A_o will have a bearing on the selection or the system which will be eventually purchased.

Step 2

Select particular MTBF and MTTR levels to be analyzed and determine the unit acquisition cost of your system in terms of the reliability and maintainability levels chosen for the system. The analysis outlined in this procedure will have to be carried out separately for each MTBF/MTTR combination to make trade-off analyses on the basis of reliability or maintainability.

The intermediate result of this portion of the analysis should be a table giving the unit cost of the system for a range of reliability (MTBF) and maintainability (MTTR) combinations. In many cases, MTTR will be relatively small and will have little effect on the availability calculations. However, on some systems whose use requires quick repair when failures are discovered (e.g., missiles and missile launchers), the MTTR will be a critical factor and the use of a fixed average regardless of the system's MTBF may lead to incorrect A_O conclusions. If MTTR is a critical factor in the analysis, a table of the following type should be developed giving unit costs for the feasible combinations of MTBF and MTTR.

	MTBF (hours)			
MTTR (hours)	100	200	300	400 . . .
	2.0			
	2.5	Unit costs corresponding to each		
	3.0	(MTTR, MTBF) combination.		
	3.5			

If MTTR can be held reasonably constant in the analysis, the above table can be described with a graph as shown in Figure 2-4.

At this point, failures and maintainability rates of the WRAs, SRAs and piece parts will have to be adjusted to reflect the system reliability to be analyzed. They should be adjusted proportionately to be consistent with desired system reliability and maintainability.

As the acquisition process proceeds and the necessary trade-off analyses have been made in the maintainability and reliability area, the system will be well defined and these factors will be fixed to the point where analysis of alternate reliabilities and maintainabilities will not be necessary.

Step 3

Select a logistic support structure for the system. That is, specify the supply and maintenance points that can be used for the system. In the early phases of acquisition, there are frequently several possible support options which reflect the possibilities of using intermediate and depot-level maintenance and the precise locations of the individual maintenance activities.

Step 4

Each support option and system reliability values requires a reevaluation of the repair rates in the basic data set. If the selected support option does not have any intermediate-level maintenance, for example, the repair rates have to be adjusted to reflect this situation. The reliability of the system also has a direct bearing on the level of maintenance used for the individual components of the system. Typically, a level of repair analysis is carried out to determine the most cost effective way of maintaining the components of the system. The analysis carried out at this point may not be of significant value if the data does not yet have a great deal of accuracy. If the decision is to forego the level of repair analysis, use the repair rates in the basic data set (adjusted of course to reflect decisions on reliability and support structure).

Step 5

Make a life-cycle cost estimate of the fixed costs involved for the Integrated Logistic Support (ILS) that would accompany the planned use of the system and the particular support structure being analyzed. These ILS elements are described below. They constitute all areas of ILS except prepositioned spare parts costs.

The Sponsor should recognize.that cost estimating techniques, as outlined in DODI 5000.33 and DODD 4245.6 will provide, at best, relative cost comparisons for alternative systems.

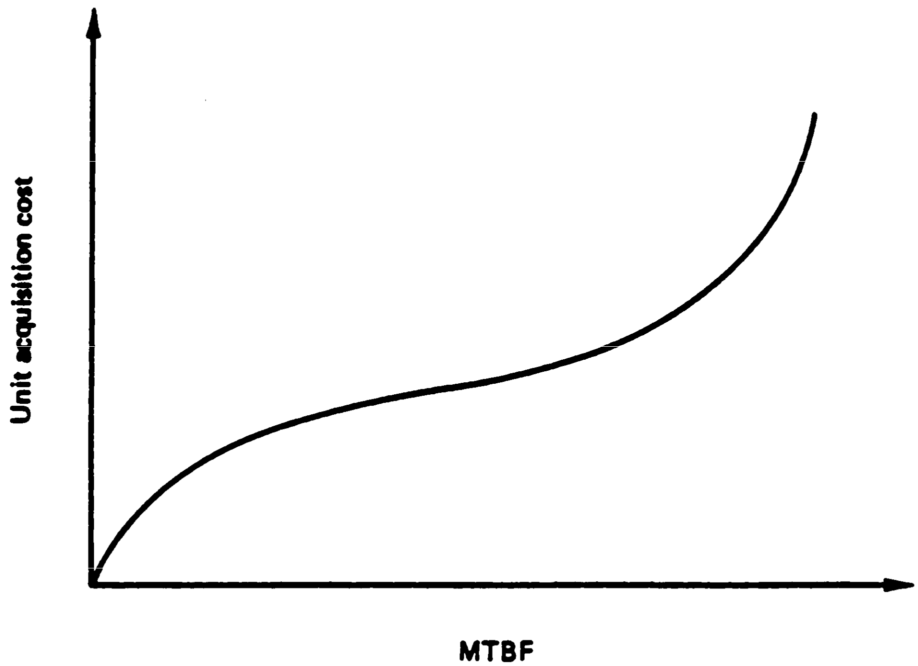

FIG. 2-4: UNIT ACQUISITION COST VERSUS MTBF

The key to using such models is to ensure consistency in assumptions and data and to evaluate results in a comparative, vice absolute, sense in examining alternative potential systems.

PRINCIPAL ILS ELEMENTS
(Less prepositioned spare parts)

Maintenance Planning and Design
Manpower and Personnel
Support and Test Equipment
Training and Test Equipment
Technical Data (Manuals and Publications)
Computer Resources Support
Packaging, Handling, Storing and Transportation Costs
Facilities
Replenishment Spares

Step 6

Estimate prepositioned spare costs. These are the costs that are placed in Aviation Consolidated Allowance Lists (AVCALs), Consolidated Ship Allowance Lists (COSALs), Consolidated Shore-Based Allowance Lists (COSBALs), Shore Consolidated Allowance Lists (CALs), and at intermediate- and wholesale-level stock points in advance of system failures. These spares, together with repair and replenishment of failed parts, are used to provide quick resupply to failed systems.

There are several ways of estimating these spare costs. It is essential that these costs be estimated using standard Navy methodology. The Aviation Supply Office and the Ships Parts Control Center will provide the Program Manager with the necessary expertise to compute the investment costs of these spare parts and predict the sparing levels for parts in the data set for each of the supply points of the support network you are analyzing.

Using this prepositioned spares package, estimate the resulting A_o of the system. For aircraft systems, the NADC SPECTRUM model or the NAVAIR CASEE model can predict resulting system A_o for the prepositioned spare parts chosen and the resupply and maintenance network that we are analyzing. The NAVSEA Tiger model can provide similar analysis for ships.

Unfortunately, standard Navy sparing methodology does not have the flexibility to select spares directly on the basis of meeting a readiness objective. Sponsors should, therefore, encourage the use of so-called "optimization" sparing techniques by the Program Manager to determine the sparing cost versus system readiness relationships for the system being evaluated. In many cases, an optimization approach to sparing will yield the most cost-effective sparing package for a new system and, where the cost versus effectiveness trade-offs dictate, the Sponsor should request (from OP-41) authority to use such a non-standard methodology. Clearly, if the readiness objective of the system cannot be met by standard sparing techniques for consumer-level spares and repair parts, Op-41 must be petitioned to allow the use of an optimization model, such as the Availability Centered Inventory Model (ACIM), in determining the prepositioned spares requirements for a system. ACIM can select spare requirements to obtain maximum readiness at an arbitrary cost. Once reliability, maintainability and the elements of ILS have been fixed (as we have done in steps 1 through 5), the parameters necessary to execute ACIM with the data base should be available and ACIM can be used to determine the cost of the required prepositioned spares that are necessary to support an arbitrary A_o level. ACIM is but one of several optimization models which are available as alternatives to standard Navy sparing methods for consumer-level inventories when the readiness objective of the system cannot be met by normal methods. Current Navy policy on the use of non-sparing methodologies is provided in NAVSUPINST 4442.14 (NOTAL). The Naval Supply Systems Command (SUP-042) can provide the Sponsor with the technical and management expertise to evaluate the appropriateness of any given sparing model for a particular system requirement.

Step 7

Using the unit acquisition cost of the system, determine the cost of the total system buy. Add to this cost the sum of the costs of the ILS support other than prepositioned spares. We will denote this sum of costs x. For each A_o value considered, compute the cost of spares required to support this A_o via the ACIM model. This cost plus x is the life-cycle cost of supporting the corresponding A_o level. Since ACIM can only be used on an exception basis, compute the cost of buying prepositioned spares with standard Navy sparing and compute the corresponding A_o. The end result of the analysis is a graph similar to Figure 2-5.

The information displayed in Figure 2-5 can be used in conjunction with the A_o to effectiveness relationship developed for the system alternative to determine the most appropriate sparing methods for the alternative being considered, and in turn, to select the system concept to be demonstrated or validated in the next phase of acquisition. It is not our intent to give a formula for making this decision. However, it is advisable to examine the A_o level achieved under standard Navy sparing policies. If this A_o level supports established mission effectiveness objectives, then this A_o threshold value should become the A_o threshold for analysis of other alternatives.

The above procedure should be used to analyze different systems, alternative support networks for a given system, and alternative reliability and maintainability requirements for the system. By repeatedly carrying out the seven-step procedure outlined above, we can derive cost-to-A_o relationships for each possible alternative we wish to consider. By incorporating these cost-to-A_o relationships for different alternatives in a single graph, we may select the low-cost alternative consistent with the A_o threshold range established. Figure 2-6 shows graphs drawn for two alternatives.

Note that we can compare the systems on the basis of the A_os attained under standard Navy support policies as well as under the "spare by exception" ACIM policy. Once the life-cycle cost analysis is completed, a decision by the Sponsor as to the specific system to be developed culminates in a Milestone I request to proceed with demonstration and validation of that specific system concept. In Figure 2-6, the Sponsor would select alternative A for validation and demonstration recognizing that to meet the required A_o threshold, nonstandard sparing will be required.

Documentation Required

As discussed earlier the cost-benefit analysis of A_o is an inherent part of the DCP/NDCP required at Milestone I. Backup or supporting documents include the PILSP and technical appendices to the DCP/NDCP. While there are no specific additional documentation requirements related specifically to cost-benefit analysis of A_o prior to Milestone I, the Sponsor should ensure that all assumptions, data sources, and computations are retained in program files. The system concept which provides requisite A_o coverage at lowest life-cycle cost should be selected at Milestone I for validation and demonstration.

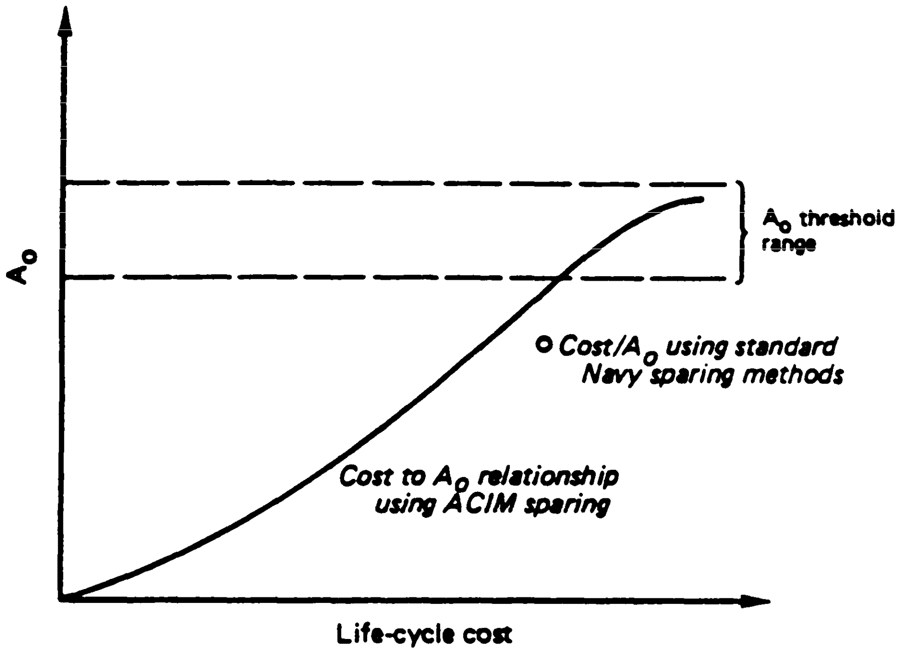

FIG. 2-5: A_o VERSUS LIFE-CYCLE COST

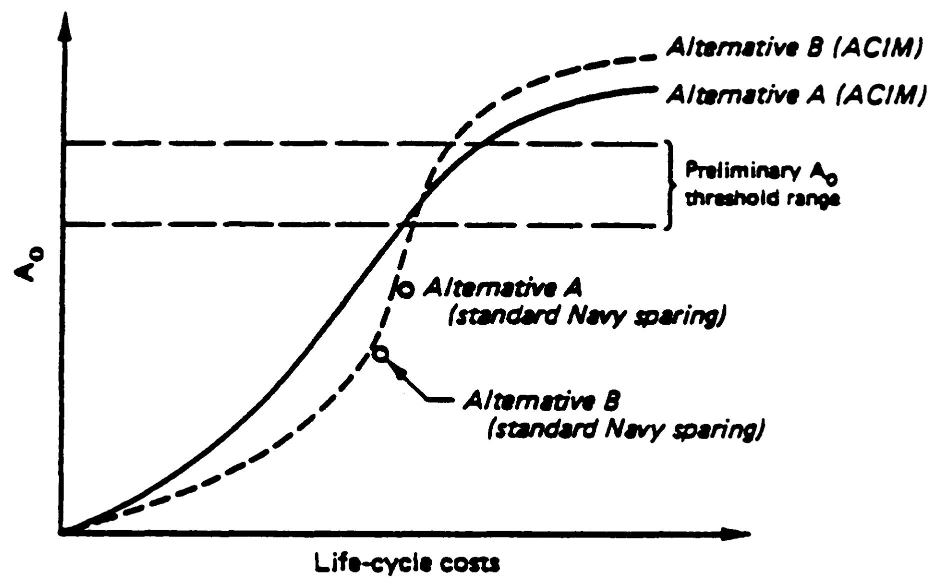

FIG. 2-6: LIFE-CYCLE-TO-A_o RELATIONSHIP

1. • Select one of the systems proposed to met required operational capability

• Establish baseline (paper) prototype system with baseline R&M parameters

• Establish operating characteristics of system (e.g., optempo) and total buy quantity

2. • Set system reliability and maintainability values to be analyzed and determine system unit cost for these parameters
    - Requires capability to estimate unit cost on basis of system reliability and maintainability

• Adjust baseline R&M parameters and unit costs of systems components if necessary to reflect chosen system reliability and maintainability

3. • Establish a logistic support structure for the system (resupply and maintenance points)

4. • Readjust repair rates in basic data set to reflect repair capability at various echelons of support
    - Do level of repair analysis if quality of data permits

5. • Estimate ILS support costs--other than prepositioned spares
    - Manpower and Personnel
    - Support and Test Equipment
    - Training and Test Equipment
    - Manuals and Publications
    - Computer Resources Support
    - Packaging, Handling, Storing and Transportation Facilities
    - Replenishment Spares

6. • Estimate prepositioned spares costs using standard Navy methodology and estimate resulting A_O using assumptions made in entire analysis

• Use ACIM to estimate prepositioned spares costs for various A_O objectives

7. • Construct Life-Cycle Cost to A_O graphs

FIG. 2-7: FLOW CHART OF GENERAL COST-TO-A_O METHODOLOGY